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Real-time estimation of time to procedure completion using AI-powered Surgical Intelligence

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Introduction

Operating room efficiency is especially important in today's environment. It is impacted by many intraoperative factors, including surgeon technique, procedure complexity, patient comorbidities, surgical aproach, and more. These factors contribute to the variability in surgical performance and therefore, efficiency. One of the key metrics used to assess operating room efficiency is procedure duration.

We developed a method that provides a real-time estimate of the time to surgical procedure completion (ETC). Our suggested approach relies solely on raw intraoperative, intracorporeal, footage. No human involvement is required for annotations nor is any previous knowledge of the surgeon's experience or patient's medical history utilized.

Data

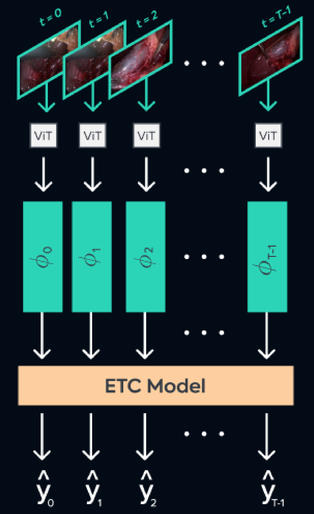
- A large-scale dataset containing 2,400 Laparoscopic Cholecystectomy videos
- Varying durations: Min=5 minutes, Max=218 minutes

	# of Videos	Mean [minutes]	STD [minutes]	Max [minutes]	Min [minutes]
Training	1,434	38	24	218	5
Validation	366	36	22	140	7
Test	600	38	22	150	6
Full Dataset	2,400	38	23	218	5

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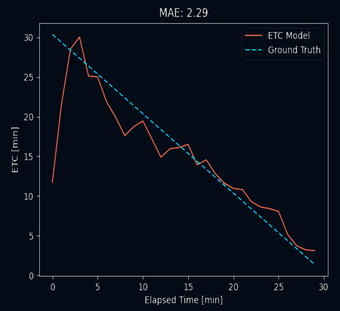
Methods

We leverage machine learning to process the surgical video and provide a minute-by-minute estimation of the time left until procedure completion. Video processing is performed sequentially, and therefore the prediction relies on current and past information only. In other words, the model takes into account data spanning from the beginning of the procedure to the current time point, while maintaining particular focus on events taking place in the present and immediate-past. This design is essential to enable real-time estimation of the time left to complete the procedure.

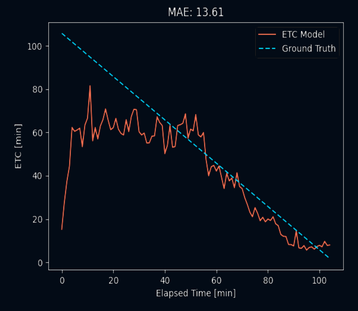


Results

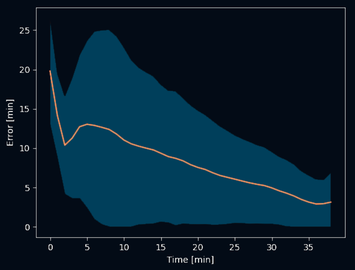
The average Mean Absolute Error (MAE) over all videos in the test set is 7 minutes.



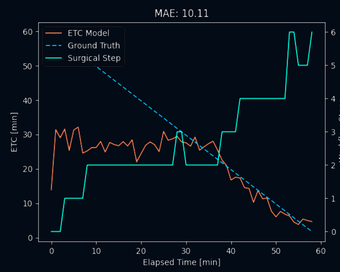
A 30 minutes Laparoscopic Cholecystectomy video with completion estimation predictions per minute. The average MAE is less than 10% of the video duration.



A 2 hours Laparoscopic Cholecystectomy video with completion estimation predictions per minute. The average MAE is about 10% of the video duration. However, the errors are mainly at the beginning of the procedure, where the estimation was relatively constant.

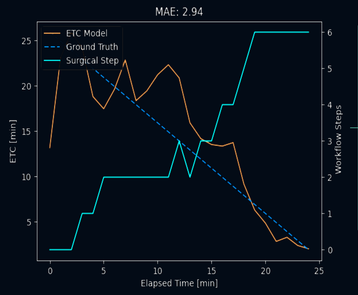


MAE Error Graph that provides insights on how the error progresses in different temporal segments throughout the video. The mean and standard deviation over all test set videos shows that the mean error and variance decrease as the procedure progresses, which is the expected behavior.



A 60 minutes Laparoscopic Cholecystectomy video with completion estimation predictions per minute and surgical workflow steps annotations.

At the beginning of the procedure, the estimation was about 30 minutes, but due to an unusual and prolonged **Dissection and Skeletonization** step, the predictions remained constant until the next step, **the Division of Cystic Structures**, started taking place.



A 25 minutes Laparoscopic Cholecystectomy video with completion estimation predictions per minute and surgical workflow steps annotations.

The ETC model estimated a 25-minutes surgery within the first few minutes and followed the correct time as the surgery progressed.

Discussion

The ability to forecast a surgical procedure's end time has numerous implications when thinking of departmental workflow efficiency. These include, for example, optimizing OR scheduling, reducing departmental management unknowns, and providing better allocation of personnel. Additionally, in complex cases where the procedure is not following a routine surgical plan, real-time prediction of time until procedure completion can serve as an important indicator, alerting colleagues outside the operating room that their immediate attention might be needed.

Real-time estimation of time to procedure completion is a fundamental building block of Surgical Intelligence Platforms. It adds an additional layer of information that provides surgeons and management with unprecedented insight into operating room efficiency.